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² Shapley, Harlow and Davis, Helen N., *Astrophys. J.*, Chicago, Ill., **51**, 1920 (140-178).

³ Von Zeipel, H., *Annales de l'Observatoire de Paris, Memoires*, **25**, 1908 (F1-F101).

⁴ Shapley, Harlow, These PROCEEDINGS, **6**, 1920 (293-300).

⁵ *Ibid.*, Mt. Wilson Contribution No. 155, 1917 (1-12); No. 175, 1919 (1-13), p. 10.

THE INFLUENCE OF ENVIRONMENT UPON DEVELOPMENT

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Read before the Academy, April 27, 1920

During the last ten years I have carried on a number of investigations on the relative influences of heredity and environment upon human types. On the whole the results show that each hereditary type can be considered as stable only in a stable environment, and that with a change of environment, many of the characteristic features of the body undergo changes. These results have been corroborated later on by investigations on immigrants in Boston and in certain respects also by Dr. Hrdlička's observations on Americans whose ancestors have been residents of this continent for several generations.

Ever since Gould and Baxter's investigations on the soldiers enlisted during the war of the Rebellion and since Bowditch's investigations of Boston school children, it has been known that the bulk of the body differs not only according to descent, but also according to social position of the child. The children of the poor are not so tall as the children of the well-to-do. We have, however, never been able to establish definitely whether children who are small for their ages will also be small as adults, or whether a compensatory growth occurs during the period of adolescence. I have shown in previous investigations that children who are retarded will at a later time have a much more rapid growth than children who in the early years of their lives are accelerated. This observation has been confirmed by a study of material which I placed at the disposal of Dr. Wissler. At that time, however, we were not in a position to extend these observations up to the adult stage.

Through the courtesy of Mr. Wilson Farrand, Headmaster of the Newark Academy, I have been able to collect observations on about 120 individuals whose measurements extend from the 11th year to adult life. The study of this series shows conclusively that from 11 years on, a short child will also be on the average short as an adult, while a tall child will be tall as an adult. The absolute amount of increment for a short child, from the age of 11 years up is, however, considerably larger than the total increment for a tall child of the same age, so that the previous observation may be extended for the whole period of growth. It seems likely that the relation between initial stature and increment will be

much slighter for earlier years, but no material is available relating to this question. A more detailed study of the relation between increment and stature shows that the increment cannot be represented as proportional to the deviation of stature from the norm, but that a more complex relation prevails. This is evidently due to the fact that at a given age there are, among short individuals, a considerable number who are retarded in development and that the number of those retarded decreases rapidly with the increase of stature so that among tall children of a given age those of accelerated development prevail. Since the increments of stature from ten years on to the adult stage cannot be expressed by a linear equation dependent upon age, it follows that the correlation between increment and adult stature as dependent upon initial stature can also not be expressed by a linear equation.

In other words we have to consider two factors. On the one hand there is the effect of retardation and acceleration which is most prominent in children of low and of high statures respectively and which results in a high increment for short children and a low increment for tall children and on the other hand there is the effect of hereditary stature which results in a low increment for short children of normal rate of development and in a high increment for tall children of normal rate of development.

It would be unreasonable to assume that among individuals who by heredity would grow to be tall, there should be a few only who would be retarded; since the causes of retardation are present in the whole socially uniform group which has been studied. The children are all children of well-to-do parents, well-nourished and living in a fairly open country, attending a school in which their health is carefully looked after. The retardation must, therefore, be due partly to an hereditary determination of the period of development; partly to individual pathological or semi-pathological conditions, which are not likely to be dependent upon hereditary stature. If then we find that those individuals who are short as adults, show from 11 and 12 years on a considerable degree of retardation, this can only be explained by the fact that the retardation has a permanent effect upon the development of the bulk of the body. Considering these conditions we must conclude that the loss of stature due to retardation in early childhood is not made up during the period of adolescence. In other words, that the ultimate stature is an effect of both hereditary and environmental causes.

I have investigated the same question with a different kind of material. I had an opportunity to examine a large series of Jewish children in New York City, living under different conditions. One group were students in a private school, the children of well to do parents; the second lived under normal family conditions on the East Side of New York City; the third group were boarded children under the care of charity organizations; the fourth group were placed in an educational institution in the open

country and organized on the cottage system, being placed in houses in groups of 30 to a house. The fifth group were children who were brought up in large institutions located in the city each institution containing more than 1000 children. A comparison of the children in the private school with all the other groups brought out very great differences. I have not been able to obtain adequate material covering the whole period of growth, but at the ages from 11-13 years the differences in both males and females are very considerable indeed. Judging from the observations made by Jacobs in London, it is safe to assume that these differences would be found to continue up to the adult stage.

In groups of children under public care continuous records were available and a comparison of the measurements of the various series of children measured on the date of commitment to public care showed that these series and that of children in normal East Side homes are strictly comparable. The statures and weights of individuals committed to a large institution, to an institution run on the cottage system and those placed in families under the care of charity organizations equaled the development of normal children from the East Side. When, however, the development of children in each group was examined, it was found that the institutionalized children lagged behind regularly. There is no doubt that the general conditions of nutrition in the large institutions, are as good as may be expected, but the whole institutional atmosphere has the effect of retarding development. Examination of adults who have passed through the asylums showed a similar effect. The average stature of adult men and women belonging to this group is about 2 cm. less than that of normal individuals of the East Side. The results obtained in an institution run on the cottage system are more favorable. While the average statures and weights are not quite up to normal, the differences are very slight. Children who are boarded in families, are in every respect comparable to the normal Jewish child in East Side families. There is only one exception to this rule. Children who are excluded from one of the institutions referred to and who are boarded in families are considerably less favorably developed than institutional children. This, however, is obviously due to the method of selection, because only children with pronounced pathological conditions are boarded out by the institution in question.

I was interested in the question whether the differences in development are due to physiological retardation and, partly for this reason, partly on account of our lack of knowledge of conditions of dentition, I collected extensive data on the eruption of teeth among the children here referred to. The observations were made by Dr. Milo Hellman to whose interest in the investigation I am greatly indebted. I have calculated before from data at hand what seems the most probable time of eruption for different teeth. In 1915, I collected similar material in Porto Rico

which was elaborated by Mr. Leslie Spier. Other material was placed at my disposal by Dr. Carl Roesse of Dresden, whose investigations on the relation between anthropological form and the condition of teeth are of fundamental importance, and finally I used a large series of casts found in the offices of orthodontists, for which series I am obliged to the good offices of Dr. Hellman. The series previously published by me suggested that the difference in period which characterizes the development of the two sexes, is not found in the development of the teeth. As I have pointed out before, the development of the head shows, that a sexual difference amounting to about $1\frac{1}{2}$ years in the rate of physiological development occurs about the fifth year, and we know that this difference increases to a little more than two years at the time of maturity. The time of the eruption of the permanent canines and of the premolars is between the tenth and eleventh years. During this time the normal difference in regard to physiological development between the two sexes is approximately a year and one-half, perhaps a little more. For the teeth, however, we obtain a difference of less than $\frac{1}{2}$ a year, which shows clearly that the dentition of males and of females must possess definite secondary sexual characteristics. An investigation of the size of the teeth does not bring out any very striking differences. E. Mühlreiter (*Anatomie des menschlichen Gebisses*, Leipzig 1891, pp. 128, 129) in his investigations of the teeth, has suggested that there are characteristic differences in form. Further investigations, however, will be necessary in order to show whether the physiological difference in development is accompanied by a morphological difference in form.

I expected that, if there should be physical retardation, we should find among the children of the well-to-do an early development of the permanent teeth and among the children of the poor, a later development. However, just the reverse was found. The eruption of permanent teeth among institutionalized children showed an acceleration of approximately eight months. I think this puzzling phenomenon may be explained by the fact that in the dental care of institutional children there is a strong tendency to remove the deciduous teeth as soon as they show decay, and that the removal of the teeth acts as a stimulus upon the development of the permanent teeth. Possibly the conditions in Porto Rico, where we also find an unusually early eruption of permanent teeth combined with a marked retardation in the development of stature, may be explained in a similar way; namely, by early decay of deciduous teeth which brings about an early loss of the teeth. I am still engaged in an investigation of the eruption of the deciduous teeth in relation to bulk of body and I hope to report on this subject at a later time.

The evidence that may be derived from a study of stature and weight alone indicates that the under-development of the children in charitable institutions is due to retardation.

On the whole the observations here reported confirm the conclusion that environmental conditions play an important part in the determination of the bodily form of the adult. It is obvious, therefore, that explanations that take into account only hereditary causes cannot satisfactorily account for the observed phenomena. This is particularly true of stature and weight, which appear extremely variable in the same lines of descent, according to the environmental conditions in which the individuals live.

THE POSSIBILITIES OF THE ROCKET IN WEATHER FORECASTING

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Communicated by C. G. Abbot. Read before the Academy, April 27, 1920

Most Desirable Conditions for Obtaining High Altitude Data for Weather Forecasting.—It is well understood that the pressure, temperature, wind velocity, and moisture content, which obtain at the top of the troposphere, i.e., at the 10 km. level, would be of much importance in weather forecasting; making possible the prediction of surface conditions many miles distant from the place of observation.

The data would obviously be of greatest value if obtained simultaneously at a number of separated stations. If this were done, an accurate weather map, representing conditions at a definite high elevation could be made, and compared with that representing surface conditions. Such a high altitude weather map would also be of obvious importance in aviation.

It is evident that the time of ascent should be as short as possible, not only in order that the data for the various stations should be obtained simultaneously, but also in order that drifting by the wind, and the consequent difficulty of recovery of the apparatus, be reduced to a minimum. The descent should also be as rapid as possible, for the same reasons, with proper arrangements to prevent damage on landing.

It would also be desirable, although not essential, that the instruments remain at, or near, the 10 km. level for from one to five minutes.

In short, then, the most desirable method of obtaining high altitude data for weather forecasting, would consist in the sending of instruments to the 10 km. level daily, from a number of stations, the ascent and descent being as rapid as practicable; provision further being made, if desirable, for maintaining the instruments at this level during an appreciable interval of time.

The Rocket Method as a Means of Realizing These Ideal Conditions.—Although the ordinary rocket has a vertical range of but a few hundred